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RESEARCH MEMORANDUM

LOW-SPEED CHARACTERISTICS OF A WING HAVING 63° SWEEPBACK AND UNIFORM CAMBER

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
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SUMMARY

Low-speed tests were made of a semispan tapered wing with the leading edge swept back 63° and having the NACA 0010 section cambered for a lift coefficient of 1.0 perpendicular to the leading edge to determine the extent, if any, to which the stability characteristics could be improved by cambering the wing. The data, obtained at a Reynolds number of 3.7×10^6 based on the mean aerodynamic chord, include pressure distributions, lift, drag, and pitching-moment characteristics of the wing with and without a fuselage. The results indicated no improvement in stability characteristics over those obtained previously for a wing of the same plan form but cambered and twisted for a uniform lift distribution at a lift coefficient of 0.5 and a Mach number of 1.4.

INTRODUCTION

Highly swept-back wings have been the subject of numerous investigations at low speed directed toward overcoming the longitudinal-stability difficulties encountered at moderate lift coefficients. Test results obtained on an untwisted, uncambered wing with the leading edge swept back 63° are presented in references 1 and 2. Further low-speed test results obtained on a wing of the same plan form but cambered and twisted to achieve a uniform lift distribution at a lift coefficient of 0.5 and a Mach number of 1.4 are reported in reference 3. These investigations indicated generally similar results in that large variations of the aerodynamic-center location were present for lift coefficients greater than about 0.3. These variations in aerodynamic-center location with lift coefficient were generally attributed to spanwise flow of the boundary layer and separation of the flow near the tip. The cambered and twisted wing used for the investigation reported in reference 3 was tested further with the outer half thickened in an attempt to increase the usable lift range and the results are presented in reference 4. This modification resulted in no change in the longitudinal-stability characteristics of the wing. It was therefore concluded that the losses in lift near the wing tip and the consequent large variations in stability could be attributed almost entirely to spanwise flow of the boundary layer.

It was reasoned that by utilizing camber alone, rather than camber and twist, the spanwise growth of the boundary layer might be delayed with a consequent delay in the onset of longitudinal stability changes to higher lift coefficients. In order to check this hypothesis it was decided to test a uniformly cambered wing with 63° sweepback of the leading edge and an aspect ratio of 3.5. This wing had an NACA 0010 base profile cambered for a lift coefficient of 1.0 on an a=0.8 (modified) mean camber line. This airfoil section was perpendicular to the leading edge of the wing.

The results of tests in an Ames 7- by 10-foot wind tunnel of this wing at a Reynolds number of 3,700,000 based on the mean aerodynamic chord are reported herein.

NOTATION AND CORRECTIONS

All data are presented as NACA coefficients corrected for tunnel-wall effects.

b span, feet

C_D drag coefficient $\left(\frac{\text{drag}}{q\,S/2}\right)$

C_L lift coefficient $\left(\frac{\text{lift}}{q\,S/2}\right)$

c_l section lift coefficient

C_m pitching-moment coefficient $\left(\frac{\text{pitching moment}}{q\,S/2\,\bar{c}}\right)$

c chord, measured parallel to the plane of symmetry, feet

$\bar{c}$ mean aerodynamic chord $\left(\frac{\int c^2 dy}{\int c\, dy}\right)$, feet

P pressure coefficient $\left(\frac{p-p_o}{q}\right)$

p local static pressure, pounds per square foot

p_o free-stream static pressure, pounds per square foot

q free-stream dynamic pressure, pounds per square foot

S area of complete wing (twice semispan area), square feet

x distance measured in stream direction, feet

y distance measured in spanwise direction, feet

α angle of attack of the wing mean aerodynamic chord, degrees

The coefficients were corrected for the constraint of the wind-tunnel walls as follows:

$$C_L = 0.991\, C_{L_u}$$

$$\alpha = \alpha_u + 1.548\, C_{L_u}$$

$$C_m = C_{m_u} + 0.001\, C_{L_u}$$

$$C_D = C_{D_u} + 0.0319\, {C_{L_u}}^2$$

These corrections were derived from references 5 and 6 and the subscript u denotes the uncorrected values.

No corrections were applied to the data for possible effects of leakage through the gap around the model where the base passed through the tunnel floor, nor were the possible effects of the tunnel-floor boundary layer evaluated. However, the results presented herein were obtained under identical test conditions to those for the tests reported in references 3 and 4, and hence should be directly comparable. The results presented for the wing-body combination should be almost unaffected by either the leakage or the tunnel boundary layer.

MODEL

The wing was mounted as a semispan model with the floor of the tunnel as the reflection plane, and had an aspect ratio of 3.5, a taper ratio of 0.25, and 63° sweepback of the leading edge. The dimensions of the wing are shown in figure 1. A gap of 1/8 to 1/4 inch existed between the model and the tunnel floor where the model base passed through the floor.

The wing had no geometric twist and the airfoil section in planes perpendicular to the leading edge was the NACA 0010 thickness distribution cambered for a lift coefficient of 1.0 on an $a=0.8$ (modified) mean line. The coordinates of the section employed are given in table I. Pressure orifices were located in sections parallel to the plane of symmetry at 0.200, 0.383, 0.707, and 0.924 semispan. The dimensions of the fuselage tested with the wing are shown in figure 1 and table II. A photograph of the model in the tunnel is shown in figure 2.

RESULTS AND DISCUSSION

The results of the force and moment measurements for the uniformly cambered wing compared with the results obtained for a cambered and twisted wing with approximately the same amount of camber (reference 3) are presented in figure 3 for the wing alone and in figure 4 for the wing-fuselage combination. Comparison of the pitching-moment characteristics for the two wings indicates little difference in the movement of the aerodynamic center with lift coefficient. The results indicate less drag for the uniformly-cambered wing at low and moderate lift coefficients and, as a consequence, higher lift-drag ratios for this lift range. The addition of the fuselage had little effect on the variation of aerodynamic-center location with lift coefficient, but resulted in a slight increase in lift-curve slope and more negative pitching moments at all lift coefficients.

The variation of section lift coefficient with wing angle of attack at the 0.200, 0.382, 0.707, and 0.924 semispan stations of the wing-fuselage combination (as evaluated from pressure measurements at these stations) is shown in figure 5. These results indicate the onset of a decrease in lift-curve slope at stations 0.707 and 0.924 between 1° and 2° wing angle of attack. This decrease in slope of the lift curves is apparently the reason for the forward movement of the aerodynamic center above wing lift coefficients of 0.28. Pressure-distribution measurements at wing angles of attack of 1.3° and 2.3° shown in figure 6 fail to indicate any reason for the decrease in lift-curve slope at the two outermost wing stations. Data are presented in reference 7 for a two-dimensional section of the same airfoil as that of the present wing but cambered for a lift coefficient of 0.8. For the two-dimensional airfoil a decrease of the lift-curve slope was noted at a lift coefficient of about 1.0 (corresponding to a lift coefficient of about 0.25 for the swept wing by simple sweep theory). From the data of reference 7 and other unpublished pressure distribution data for this two-dimensional airfoil, there is some evidence of separation near the airfoil trailing edge at lift coefficients of about 1.0. This separation is confined to about the last 10 percent of the airfoil chord, hence would not be observed in the limited amount of data shown in figure 6 for the rear portion of the swept wing. Observations of wool tufts on the upper surface of the swept wing were also made. These observations did indicate pronounced spanwise flow in the boundary layer near the trailing edge, but no abrupt changes in flow conditions were evident at the lift coefficients for the stability changes.

Since no basic improvements in stability were indicated for the uniformly cambered wing relative to other wings of the same plan form, this version of the wing was not considered of sufficient importance to justify a more detailed analysis of the results.

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REFERENCES

1. Hopkins, Edward J.: Aerodynamic Study of a Wing-Fuselage Combination Employing a Wing Swept Back 63°. - Effects of Split Flaps, Elevons, and Leading-Edge Devices at Low Speed. NACA RM A9C21, 1949.

2. McCormack, Gerald M., and Walling, Walter C.: Aerodynamic Study of a Wing-Fuselage Combination Employing a Wing Swept Back 63°. - Investigation of a Large-Scale Model at Low Speed. NACA RM A8D02, 1949.

3. Weiberg, James A., and Carel, Hubert C.: Wind-Tunnel Investigation at Low Speed of a Wing Swept Back 63° and Twisted and Cambered for a Uniform Load at a Lift Coefficient of 0.5. NACA RM A50A23, 1950.

4. Weiberg, James A., and Carel, Hubert C.: Wind-Tunnel Investigation at Low Speed of a Wing Swept Back 63° and Twisted and Cambered and with a Thickened Tip Section. NACA RM A50I14, 1950.

5. Swanson, Robert S., and Toll, Thomas A.: Jet-Boundary Corrections for Reflection-Plane Models in Rectangular Wind Tunnels. NACA Rep. 770, 1943. (Formerly NACA ARR 3E22)

6. Polhamus, Edward C.: Jet Boundary-Induced-Upwash Velocities for Swept Reflection-Plane Models Mounted Vertically in 7- by 10-foot Closed, Rectangular Wind Tunnels. NACA TN 1752, 1948.

7. McCullough, George B., and Haire, William M.: Low-Speed Characteristics of Four Cambered, 10-Percent-Thick NACA Airfoil Sections. NACA TN 2177, 1950.

TABLE I

COORDINATES OF THE AIRFOIL SECTION PERPENDICULAR TO THE LEADING EDGE

[Stations and ordinates given in fractions of airfoil chord]

Upper-surface station	Upper-surface ordinate	Lower-surface station	Lower-surface ordinate
0.00670	0.02071	0.01830	-0.00865
.01808	.03121	.03192	-.01011
.04224	.04662	.05776	-.01056
.06703	.05840	.08297	-.00976
.09212	.06803	.10788	-.00841
.14273	.08298	.15727	-.00492
.19363	.09390	.20638	-.00088
.24465	.10180	.25537	.00334
.29572	.10726	.30428	.00758
.39782	.11226	.40218	.01562
.49973	.11123	.50027	.02179
.60134	.10309	.59866	.02707
.70262	.08955	.69738	.02871
.80388	.06825	.79612	.02521
.90298	.03624	.89713	.01280
.95160	.01879	.94840	.00573
1.00025	.00102	.99975	-.00102
L. E. radius = 0.011			

TABLE II

FUSELAGE COORDINATES (IN.)

Station	Radius
0	0
4	1.423
8	2.670
12	3.746
16	4.655
20	5.402
24	5.991
28	6.443
30.6	6.626
40.8	7.140
51.0	7.603
61.2	7.914
71.4	8.099
81.6	8.160
91.8	8.099
102.0	7.914
112.2	7.603
122.4	7.140
132.6	6.626
142.8	5.843
153.0	4.924
163.2	3.794
164.4	3.580
166.4	2.910
168.4	1.790
170.4	0

[redacted]

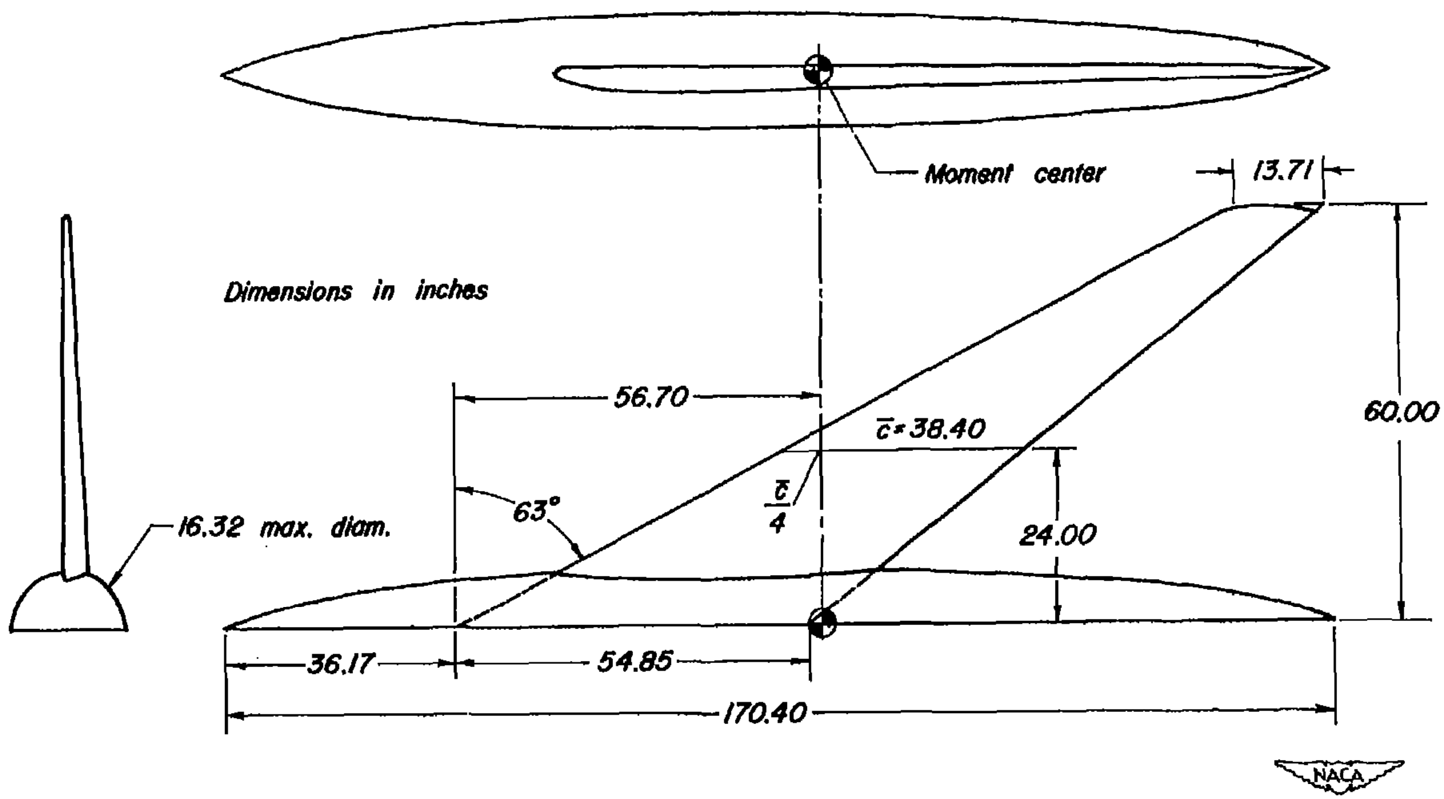

Figure 1.—The wing-fuselage combination.

[redacted]

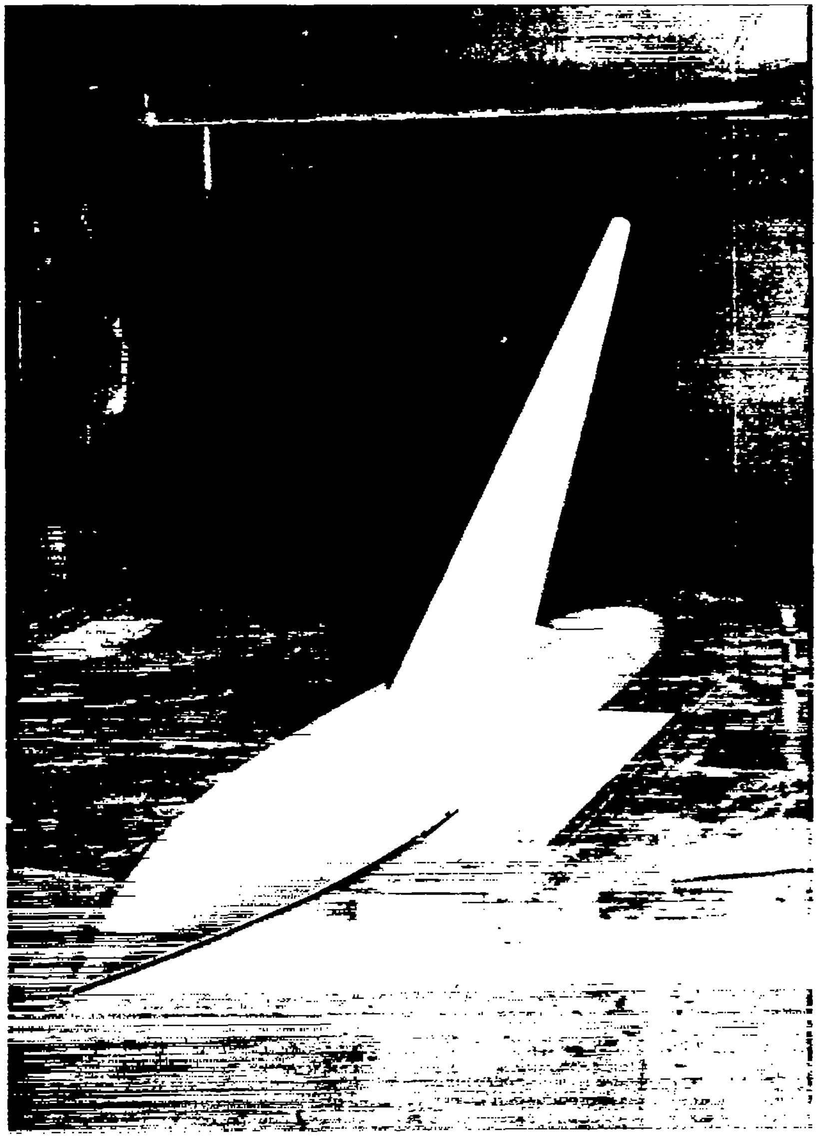

Figure 2.- Wing-fuselage combination installed in the wind tunnel.

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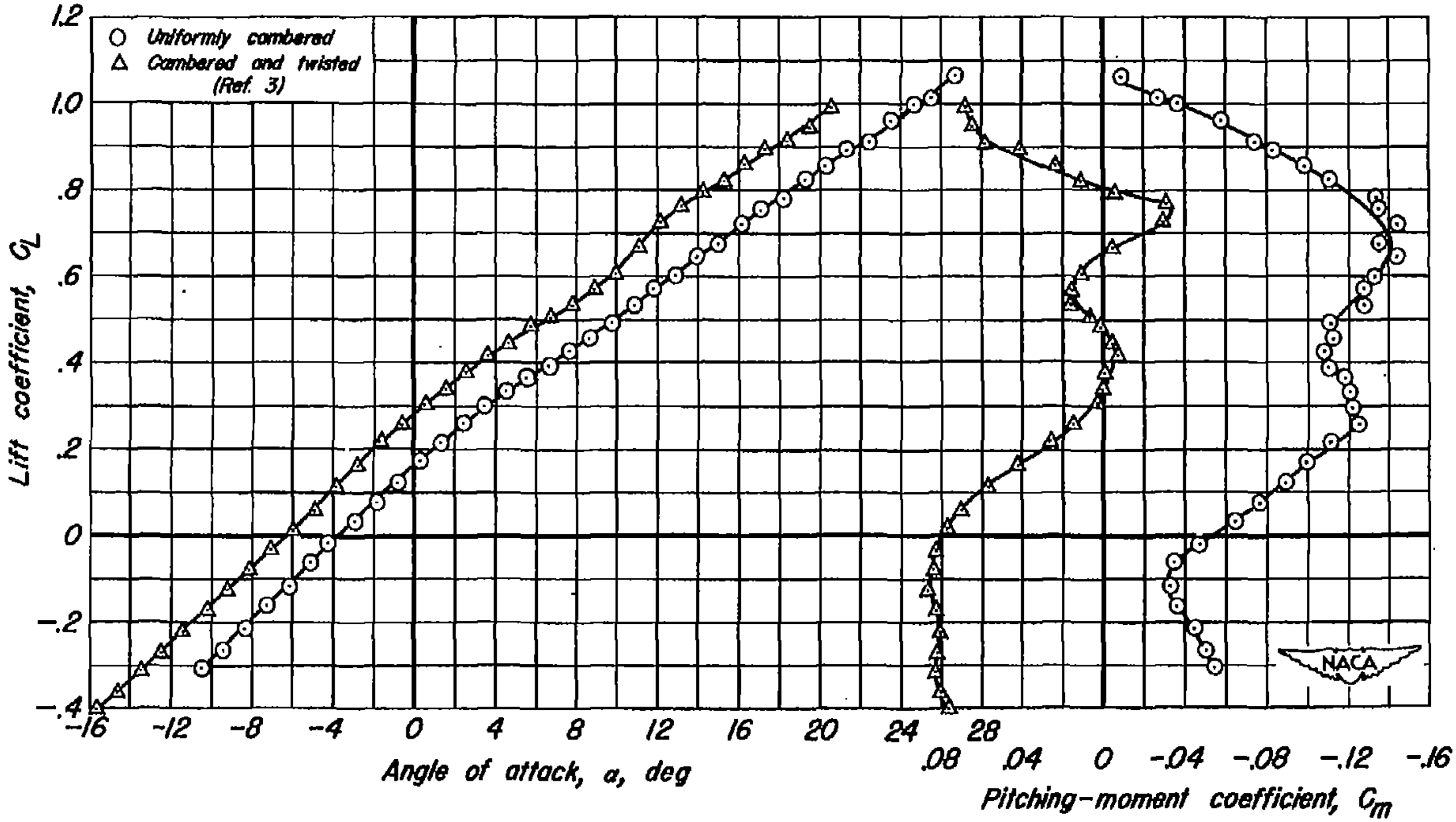
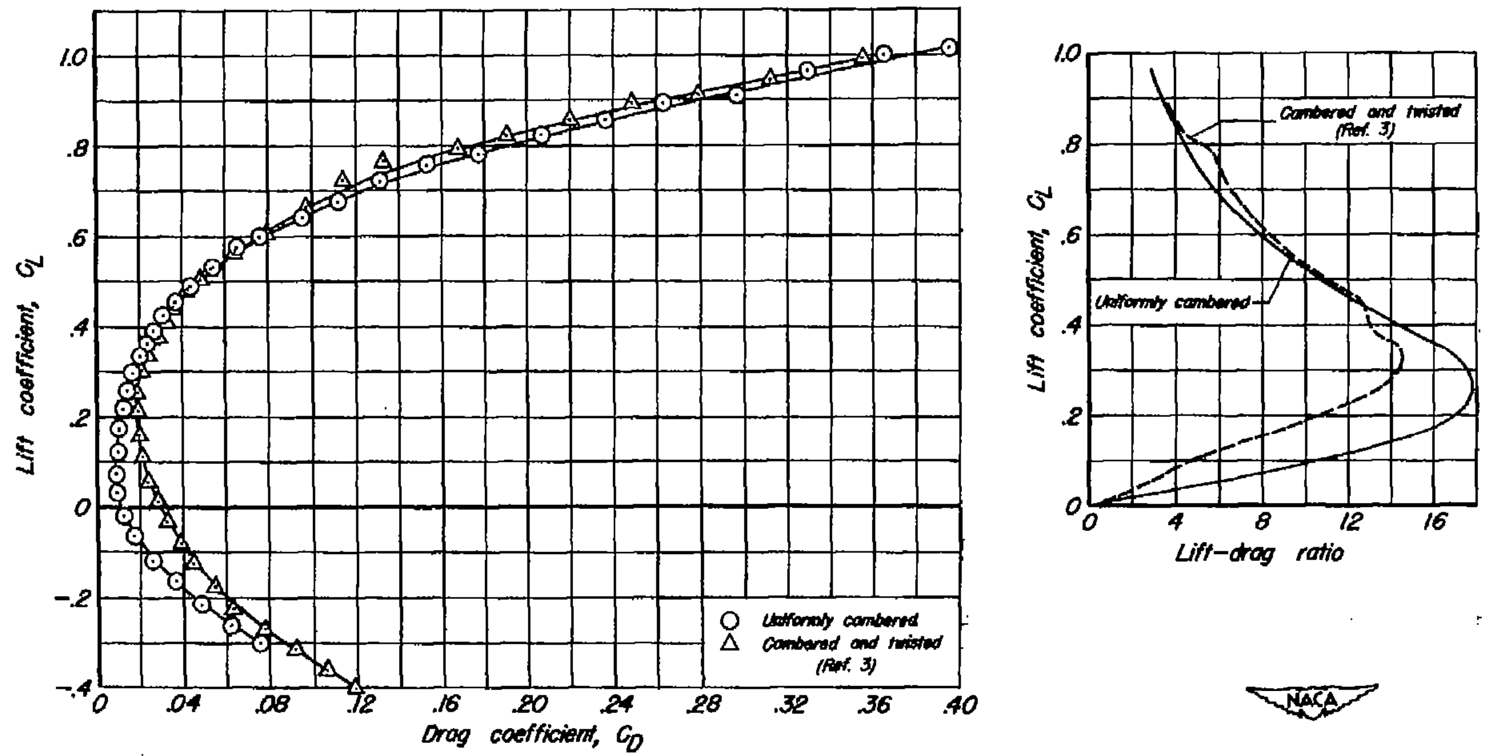


(a) Lift and pitching-moment.

[redacted]

Figure 3.—Lift, drag, and pitching-moment characteristics of the uniformly cambered wing compared with the cambered and twisted wing.

[redacted]



(b) Drag and lift-drag ratio.

Figure 3.—Concluded

[redacted]

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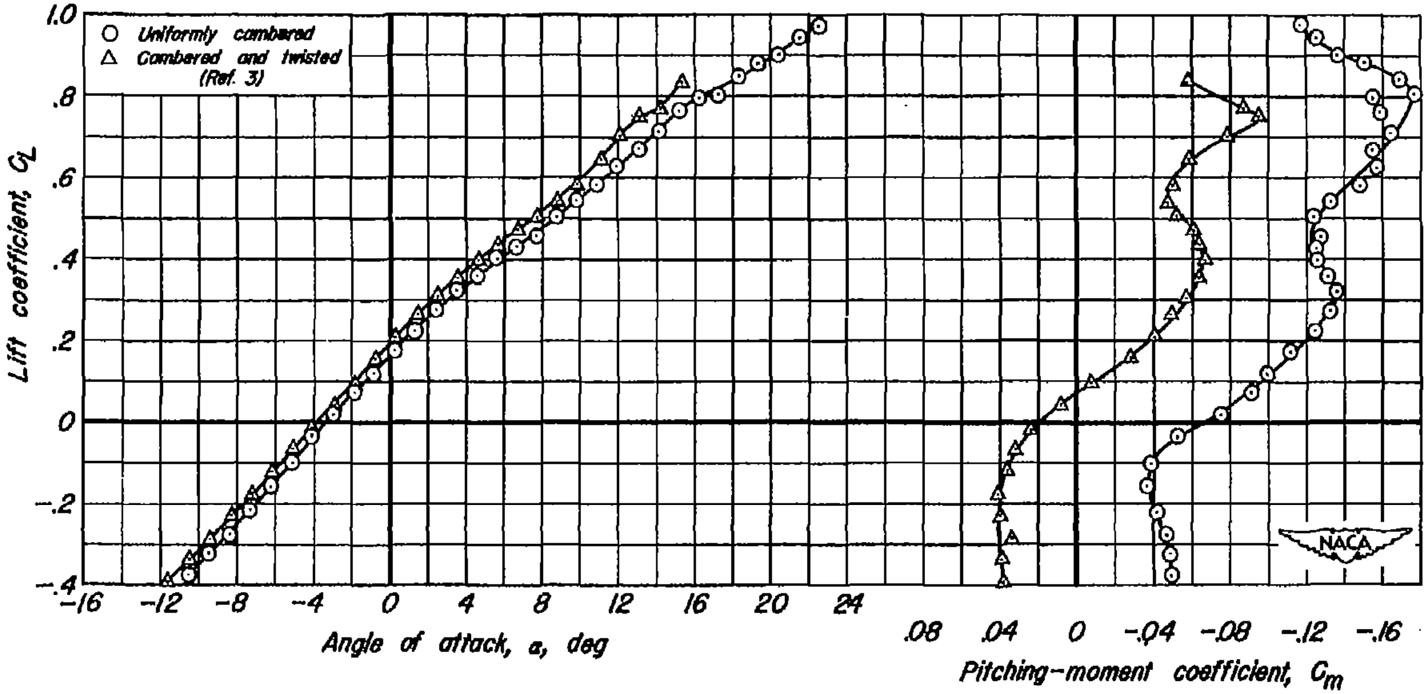
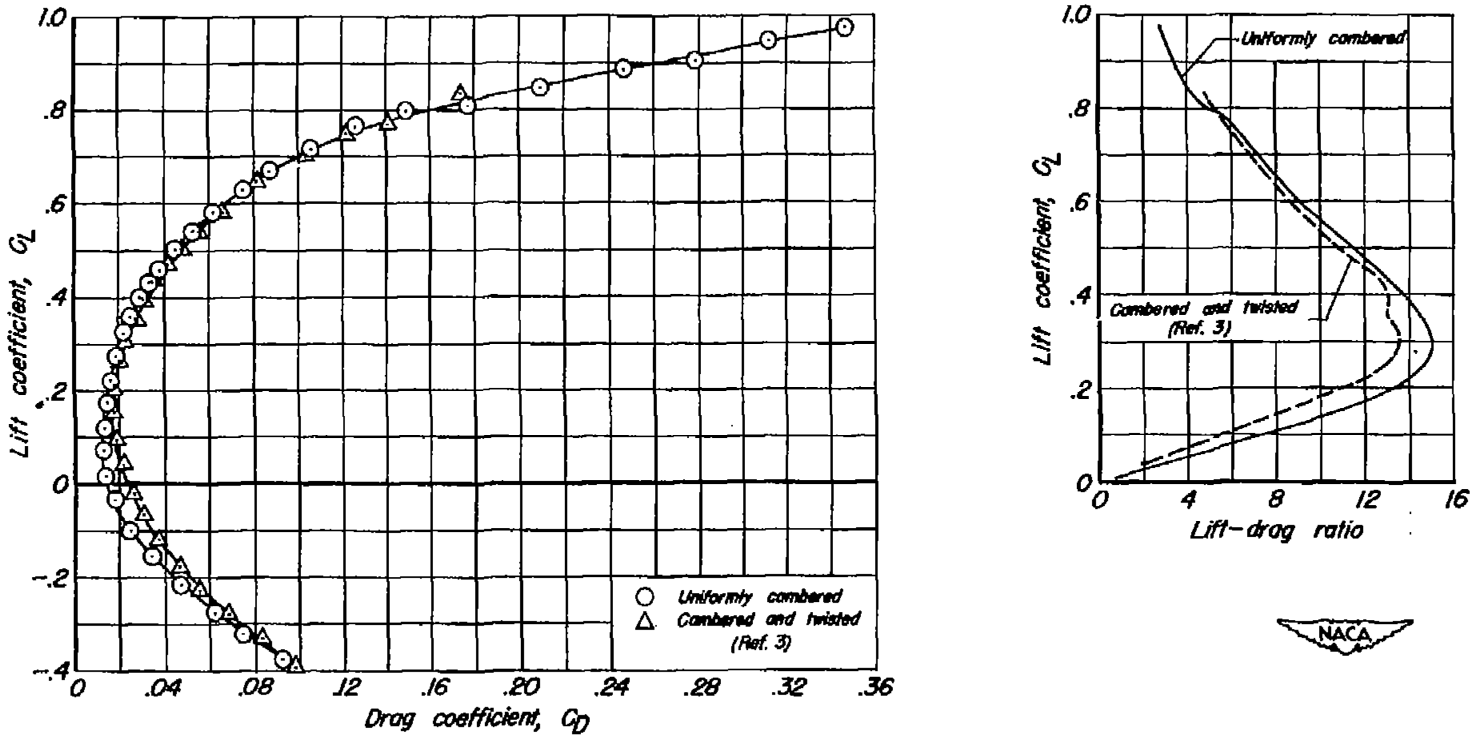


(a) Lift and pitching-moment.

Figure 4.—Lift, drag, and pitching-moment characteristics of the uniformly cambered wing with fuselage compared with the cambered and twisted wing with fuselage.

[redacted]

[redacted]



(b) Drag and lift-drag ratio.

Figure 4.—Concluded.

[redacted]

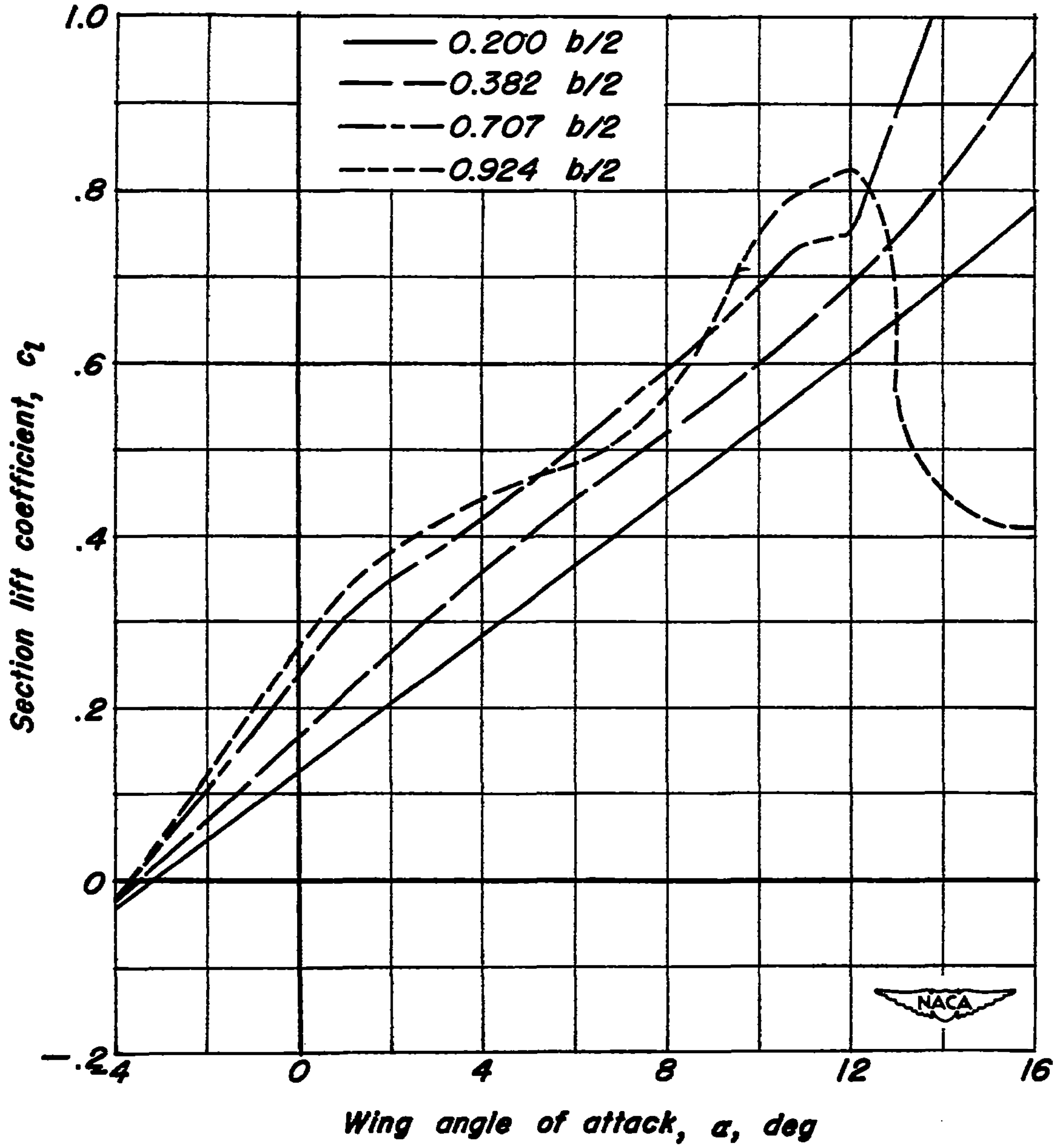


Figure 5.—The variation of section lift coefficient with wing angle of attack at four span stations for the uniformly cambered wing with fuselage.

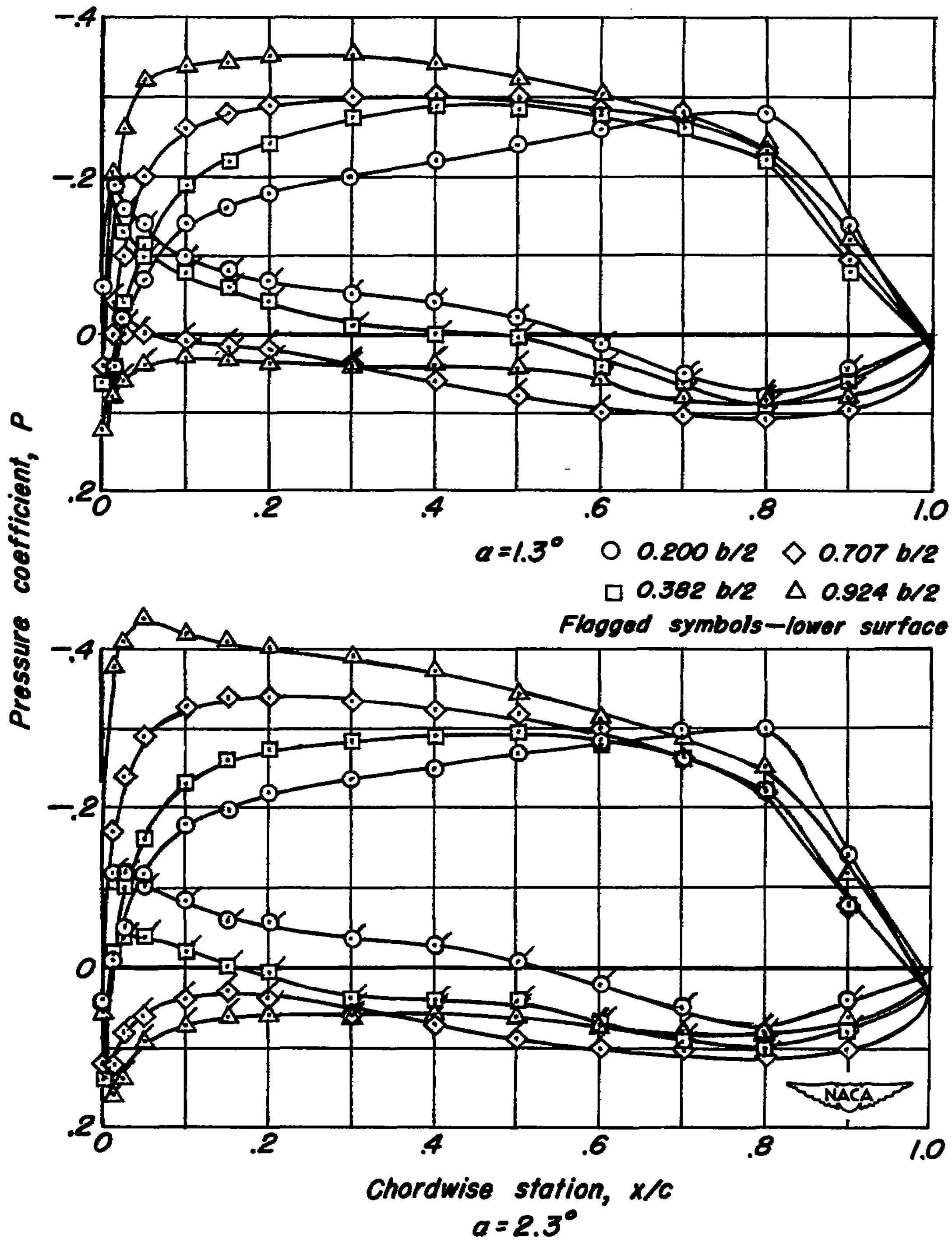


Figure 6.—Pressure distributions at two wing angles of attack for the uniformly cambered wing with fuselage.

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